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A Review: Growing Rice in the Controlled Environments

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Rice (Oryza sativa L.) is the most important staple crop. Rice is a source of essential vitamins such as vitamin C and B6, carbohydrates and other nutrients such as selenium and phosphorous. About 90% of world's rice are cultivated in Asia and Africa. China is the leading producer. It fulfills 70% income and nutrition needs of Asian population. Rice can be the potential solution to hunger and malnutrition, especially in poor, developing countries. The methods of rice growth are transplanting and cultivation media, grow in hydroponic condition and grow in soil. The production of rice is impacted by biotic stressors, which are present in a wide range of agro-climatic conditions around the world. Multiple diseases can be brought on by biotic pressures caused by climate change. To mitigate the impact of climate change and enhance rice cultivation unique germplasms are being cultivated. This review presents unique germplasm of rice and their cultivators, methods of rice cultivation, disadvantages of rice cultivation for research purpose and diseases that affect rice.

Keywords: Asia; Africa; Biotic stresser; Cultivars; Germplasm; Hydroponic; Malnutrition; Oryza sativa L.

Rice (*Oryza sativa L.*) is one of the most important staple crops cultivated in 158 million hectares supply 20% of global nutritional energy [1]. Rice feed almost half of the global population as half of the Earth's population consume rice on daily basis. It fulfills 70% calorie needs and income source of population in Asian countries, the major staple food for undernourished and poorest population of Asia and Africa, can't access or afford nutritious food. Rice, one of most strategic food matrices, not only associated with food security but also correlated employment, economic growth, regional peace and social stability [2].

More than hundred countries cultivate two distinct types of domesticated rice; Asian rice (*Oryza sativa*) and African rice (*Oryza glaberrima*) [3]. Several ecosystems such as cool or warm humid tropics, warm sub-humid tropics and warm humid tropics are suitable for rice cultivation. Based on production and water-soil requirement for rice cultivation, ecosystems can be categorized as irrigated lowlands, irrigated uplands, floating or deep-water ecosystems, rain fed lowland and rain fed upland. The rice cultivation on the basis of establishment method can be divided in two categories; direct seeded rice and transplanted rice [4].

About 75% of global rice produced per annum is transplanted under flood condition, while about 25% is direct seeded. The issues such

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as water scarcity, poor and degrading soil quality, low efficiency of nutrient work, decrease in labor availability (prefer non-farm work), enhanced greenhouse gas (methane) emission, deficiency of micronutrients, pest insect and disease, decrease in rice productivity and pervasiveness of new weed biotypes threaten the transplanted rice production system. The direct-seeded rice has been a realistic approach to conserve labor and water resources in this context as well improved rice productivity especially on fine textured soils and decrease methane emissions. However, weed management is still need to be addressed in this technology [5, 6].

Rice is the staple food that is most affected by climate change. As the rice crop is sensitive to climatic conditions, the production shows fluctuations with changes in rainfall pattern and temperature. The 32º temperature effects pollen availability and disposition, seed set and reduced the rice yield. The volatile precipitation pattern along with high temperature affect regional water demand for irrigation and affect yield [7].

The major challenge in rice cultivation is to enhance the productivity or yield in the context of climate change and exponential growth. Over the past decades, the development of hybrid crop varieties and adoption of semi dwarf alleles has shown positively affected the cereal grain yield, these achievements and efforts relies over fertilization results and on fertilizer applications; resulting in significant acidification of cropland system, water eutrophication, massive energy consumption and an economic burden on farmers [8].

In recent decade, ecological rice production system such as rice-duck, rice-fish and rice-crayfish are being used, especially in China, to fulfill protein requirement of population and tackle global warming impact without compromising rice production of the area [9]. This review presents unique germplasm of rice and their cultivators, methods of rice cultivation, disadvantages of rice cultivation for research purpose and diseases that affect rice.

Rice production and consumption

The annual global rice production is estimated to be 508.7 million tons. The global rice consumption was estimated to be 480 million tons in 2014 and projected to increase to 550 million tons in 20230, driven by economic growth in developing world and global population increase [10]. About 90% of the world's rice is produced and consumed in Asia, the consumption and production are increasing at a rapid rate in Africa.

Globally rice production is carried out by 400 million small scale farmers. China is the highly rice producing country 206 million tons, followed by India with 157 million tons rice production that is followed by Indonesia, Bangladesh and Vietnam. The difference of rice produced in India and China is mainly due to land area cultivated.

China > India > Indonesia > Bangladesh > Vietnam

Only 10% of the globally produces rice is traded. The largest importer of rice are China, Philippines, Nepal, Iran, Nigeria and EU, whereas, the topmost exporter countries are India, Vietnam, Thailand, Pakistan and USA [11].

There exist a number of concerns about rice cropping sustainability in future. The major concerns include; rice cultivation is responsible for 11% and 30% of global nitrous (N_2O) and methane (CH_4) emissions from agricultural source. The decreased growth rate, reached a plateau in major rice producing countries such as China, Indonesia, South Korea and California. The global rice production consumes 10% pesticides, 30% of irrigation water and 14% fertilizers; having several negative impacts on ecosystem. The rice production requires high labor and associated economic cost; making it less attractive for farmers, especially if governments are reluctant to provide subsidies and price support mechanism specifically for small farmers [13].

Importance of Rice

Solution of hunger and malnutrition

Rice research can be helpful in poverty eradication either indirectly (high yield with lower consumer price) or directly (high productivity and profit for farmer). The *Japonica* rice could be a potential solution of malnutrition and hunger in rice-consuming countries. The rice demand is expected to enhance with increasing population. It has capability to strengthen global food security and reduce hidden hunger [14].

Rice is most suitable raw material for manufacturing cereal-based snacks, modified starches, dietetic foods, rice-based products and pre-cooked breakfast due to its flavor, color, bland taste, better processing characteristics and hypo-allergenicity. Brown rice contains acid, dietary fibers and gamma-amino butyric acid. Black rice is a source of fiber, minerals, and phytochemicals and contain anthocyanin [15, 16].

Source of vitamins

Rice is a source of vitamin E, thiamine, pantothenic acid, folate etc. [17]. Milled rice contain small amount of thiamin. Thiamine (vitamin B1), water soluble vitamin, acts as a catalyst in decarboxylation of alpha-ketoacids and branched chain amino-acids for energy generation and functions as coenzyme (thiamine pyrophosphate) for transketolase. It also plays significant role (unidentified) in myelin sheath and propagation of nerve impulse. The deficiency of this vitamin can affect immune system, nervous system and cardiovascular system [18, 19].

Golden rice is a source of vitamin A. Golden rice, modified with transgenes from soil bacteria (*Erwinia uredovora*) and maize produce beta-carotene, precursor to Vitamin A. The golden rice substitution for conventional rice provides 57-99% vitamin A requirement in Philippines, if no other source of vitamin A is consumed. It is economically feasible and pose no extra cost to consumers, farmers and government [20]. The deficiency of this vitamin cause deaths and illness (blindness, diarrhea, and measles) worldwide, specifically affecting children. The vitamin A deficiency related measles and diarrheal illness has 94500 causalities of children under five years of age in 2003 and 105700 deaths across the globe [21].

Rice contains vitamin H or B7 (biotin), 30mcg/day required for good health. Biotin act as coenzyme for five carboxylases: 3-methylcrotonyl-CoA carboxylase, pyruvate carboxylate, acetyl-CoA carboxylase 1& 2 and propionyl-CoA carboxylase. These carboxylases perform several chemical processes in cell as amino acid metabolism, gluconeogenesis and fatty acid synthesis [22].

Source of carbohydrate

Rice (brown) contains complex carbohydrates. Carbohydrates are macronutrients, contain carbon, oxygen and hydrogen. Carbohydrate is a term for fruits, vegetable, legumes, sugar and fibers. Carbohydrates act as energy source, help in fermentation, participate in triglyceride and cholesterol mechanism and help control insulin and glucose mechanism [23].

Rice contains large quantities (78%) of carbohydrates, mostly in the form starch [24].

Carbon sequestration and climate change mitigation

The rice field can be a potential carbon pool if managed properly. The rice paddies stock 108 Mg ha-^{1} (0-100cm layer) that is approximately 10% global average of all soil types. The rice paddies stock greater carbon than croplands and grasslands. Across the globe, rice paddies stock about 14.2% of total SOC pool in croplands, 1m upper soil contains 18Pg organic carbon. Rice paddies stock 14% cropland SOC by occupying less than 9%, major factors of this organic carbon stock are anaerobic conditions and slow decomposition rate [25, 26].

In tropical and sub-tropical regions under humid and high temperature conditions, microbial activity in soil is rapid, increase in soil carbon content. Farmers apply large quantities of organic matter, increasing soil carbon stock and reducing carbon dioxide concentration in atmosphere [27].

There exists correlation between paddy field soil and organic carbon stock. However, new paddy soils sequester more carbon as compare to old paddy soils [28]. Measured 0.79 g C/ kg increase in soil organic carbon over 37 years and 0.145 g C/kg year in new paddy soil.

Tan et al. [29] estimated 0.26 Tg carbon dioxide sequestration per year from rice in China, they estimated that global carbon sequestration by rice was 4.3 Tg CO_2 per year. Practices as selection of rice verities with high organic carbon stock capacity and appropriate fertilizers could sequester carbon dioxide for decades and contribute to climate change mitigation [30].

Several researches reveal that management practices while rice cultivation can have positive influence on soil carbon fraction. This includes practices that ensure greater residue return to soil and have considerable effect on carbon stabilization. Some studies show that combined application of organic and inorganic fertilizers can improve soil organic matter in rice system. The addition of compost, crop residues and farmyard manure improve carbon stabilization in rice cultivation system. The methods or technology to improve soil organic carbon requires more research on management practices, ecological concerns, soil quality and sustainable production [31, 32].

Alternative energy source to meet future energy demand

The majority of world's energy derives from gas, oil and coal, consumed for transportation, power generation, community and industrial sector. The countries are striving for identifying alternative energy resources that mitigate climate change. One strategic approach to achieve sustainable development goals (SDGs) is use of renewable energy resources also referred as alternative energy sources. These alternative energy sources include solar energy, geothermal energy, biomass energy and wind energy.

Biomass resources are renewable organic energy resources and present in abundance, have ability to stock carbon dioxide by photosynthesis [33]. Biomass can be categorized into agricultural residues (generated by agro-industries, crops and animal farms); wood residues (generated by wood industry); municipal solid waste and energy crops. Biomass provide 35% and 3% energy in developed and industrialized countries. By 2050, biomass energy will be a substantial source to fulfill energy demand of increasing population; estimated that 90% of global population may be present in developing countries. These resources can be used in direct heating (most widespread application) or for electricity generation or to produce liquid and gaseous fuels [31]. Rice straw can be used as organic fertilizer, livestock feeding or material for cooking. Usage of rice straw can meet energy demand and also reduce the emission of pollutants in atmosphere; released by open, uncontrolled burning of rice straw.

Rice husk is about 22% of its total mass. Rice husk, a cellulose-based fiber contains 40% cellulose, 20% silica (amorphous form) and 30% lignin. The characteristics of ash (produced by burning of husk) depend on husk composition, burning time and temperature. The most researched technologies for producing energy from rice husk are pyrolysis, direct heating and gasification [34].

Rice straw is also another energy source; however, management of waste, logistics and transportation is difficult, the combined husk-straw briquettes can be used for energy generation. Energy generated by husk can reduce 80% greenhouse gases emissions as compare to energy generation by fossil fuels. Rice husk can replace 67% wood consumption, reducing 62.94% GHGs emissions. The capacity of energy production by rice husk in Indonesia is 39076 GWh/y. Pakistan can generate 1328 GWh/y, China 55302 GWh/y, Japan 2548 GWh/y and Brazil can generate 2124627 MWh/y [35, 36].

The challenges of energy generation by husk include difficulty in handling and storage, possible corrosion, accumulation of residue in combustion equipment, logistic for generation and distribution. However, methods exist that can minimize these issues [37].

Optimum conditions for rice cultivation

The factors that are required for proper rice cultivation include temperature (higher than 15 degree- Celsius; below this temperature, germination don't occur), rainfall (minimum 115 cm; rice require plenty of water), soil (riverine alluvial soil is best; also cultivated in saline and clayey soil, it requires a large quantity of fertilizers), leveled surface soil and labors availability as rice cultivation requires extreme labor work [38].

The optimum temperature for rice growth is 25-35 degree Celsius. The cold temperature lowers yield and grain production and affect phonological stages. Low temperature in vegetative stage can cause low number of seedlings, slow growth, reduce tilling, increase plant mortality, reduce seedling vigor and increase in growth period. At reproductive stage it causes panicle sterility. The critical stages for cold temperature are booting and germination, flowering is the most sensitive stage [39].

Heat stress, abiotic factor limit plant productivity and production. High temperature is detrimental for reproductive and vegetative stage. The productivity of rice crop drops 15% with 1ºC increase in temperature. It also causes reduction in grain yield and biomass. So, as climate change phenomena is more pronounce, rice productivity is also decreasing, requires a counter back mechanism. New verities with temperature tolerant characteristics are needed to maintain crop productivity and global rice supply [40].

Rainfall is necessary for rice cultivators and productivity, rice cultivation requires large quantity of water, rainfall is best option as it reduces energy and ground water dependence. However, heavy rainfall is suitable for tilling stage leading to increase in weight of rice grain, on the contrast, at flowering stage, muddy soil due to heavy rainfall causes severe damage to rice plants. The sediments in muddy soil create hurdle for photosynthesis. The decreased rainfall alters panicle weight and reduce rice crop production by increasing spikelet sterility [41].

Rainfall has strong impact on rice yield, the climate change impact rainfall pattern mainly due to sea level rise, altering the rice productivity along the globe. To cope rainfall changes and get maximum growth it requires conversion of cropping pattern, higher rice yield and efficient fertilizer application [42].

The large quantities of fertilizers are required for good yield and productivity. Iron (Fe) is necessary for metabolic reactions (respiratory, electron transport chain, pigment synthesis) and maintain physiological processes in plants. Iron and cadmium have negative correlation, so, it decreases the Cd translocation by foliar application. Cd is a major environmental concern and may enter in food chain via translocation mechanism from soil to plant and then humans and other animals. Fe fertilizers decrease cadmium translocation and promote rice yield [43]. Other nutrients are also required for increasing and maintaining yield, stocking soil organic carbon, maintain soil health and nutrient availability, most important is nitrogen fertilizer [44].

The issues of temperature, precipitation or fertilizer needs can be resolved by using unique germplasms of rice. Other changes that could be made include technological changes, cultivation pattern changes, usage of animal manure to fulfill fertilizer demands etc.

Methods of growing rice

Transplanting and Cultivation media

Transplanting, common practiced method of weed control for puddled fields. It is conventional method, require more labor but less seeds, while the crops grown by this method take long to grow. Majority of rice cultivation in Asia is done by transplanting. Depending on soil type 25-30 person per day are required for one hectare to cultivate rice by this method. It prevents heat and cold damage during growing stage and facilitates easy weed management.

Transplanting can be done manually (labors) or mechanical rice transplanters can be used. *Manual transplantation* is most widely used method for rice cultivation. For this method, seedlings are first grown in a nursery and then transplanted into the field where to cultivate rice. There are two methods of manual transplantation; random (seedling without any specific space or distance between plants) and straight-row method (uniform pattern or spacing between plants). Plant spacing is an important factor, may increase 25-40% yield. Manual transplanting requires intensive labor work, may need 250-350 man per day in one hectare. As manual transplanting requires immense labor work, it's being replaced by mechanical transplantation [45].

The mat type trays are used to grow seedlings in *mechanical transplanted* rice, these seedlings are then transplanted into the field through mechanical rice transplanter. This mechanical rice transplanter can be power operated or manual operated. On the basis of power operated, it can be categorized in self-propelled riding type, manually operated types and self-propelled walk behind types. The labor requirement is decreased by this method. This type of transplantation needs 15cm thin water layer at nursery transplantation and approximately 4cm at the time of seedling transplantation [46].

The flooded transplanted system for rice cultivation are water and labor intensive, have low nitrogen efficiency and release large amount of greenhouse gases. Therefore, direct seeding method is used as it requires less energy and labor and release less pollutants in the atmosphere. Transplanted rice shock delay rice heading and leaf development [47].

Hydroponic method to grow Rice crop

Hydroponics is a technique of growing plants in nutrient solutions with or without the

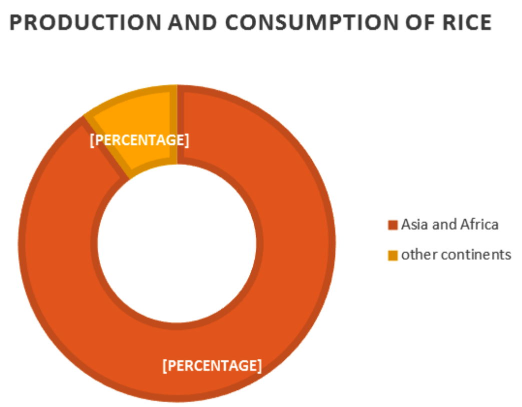

Fig. 1. Global production and consumption of rice

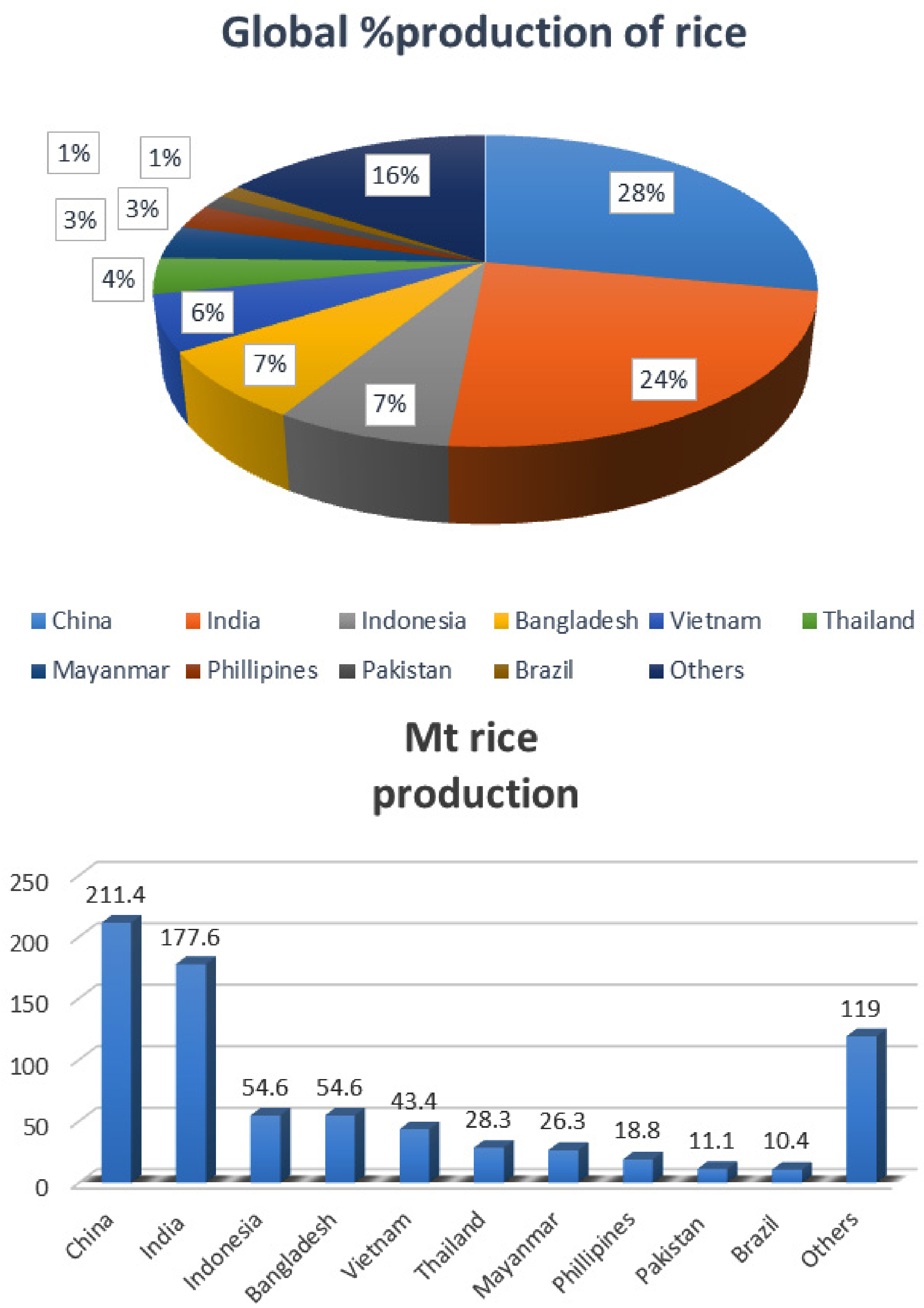

Fig. 2. a) Global production of rice Percentage % based b) Global production of rice in million tons in different countries around the globe [12]

use of an inert medium to provide mechanical support [48]. It can also be defined as a technique of growing plants in soil-less condition with their roots immersed in nutrient solution. [49]. A method of plant cultivation that is becoming more and more popular can also solve issues with conventional and traditional rice farming, including irrigation systems, a lack of available land for planting, the management of nutrient inputs, pest control, and a decline in community support for paddy farming, especially among the younger generation. It is possible to cultivate a wide variety of crops hydroponically. Since hydroponically growing is expensive, it is standard practice to grow the highest-value crops. Even though hydroponic rice farming is still a relatively new practice, there have

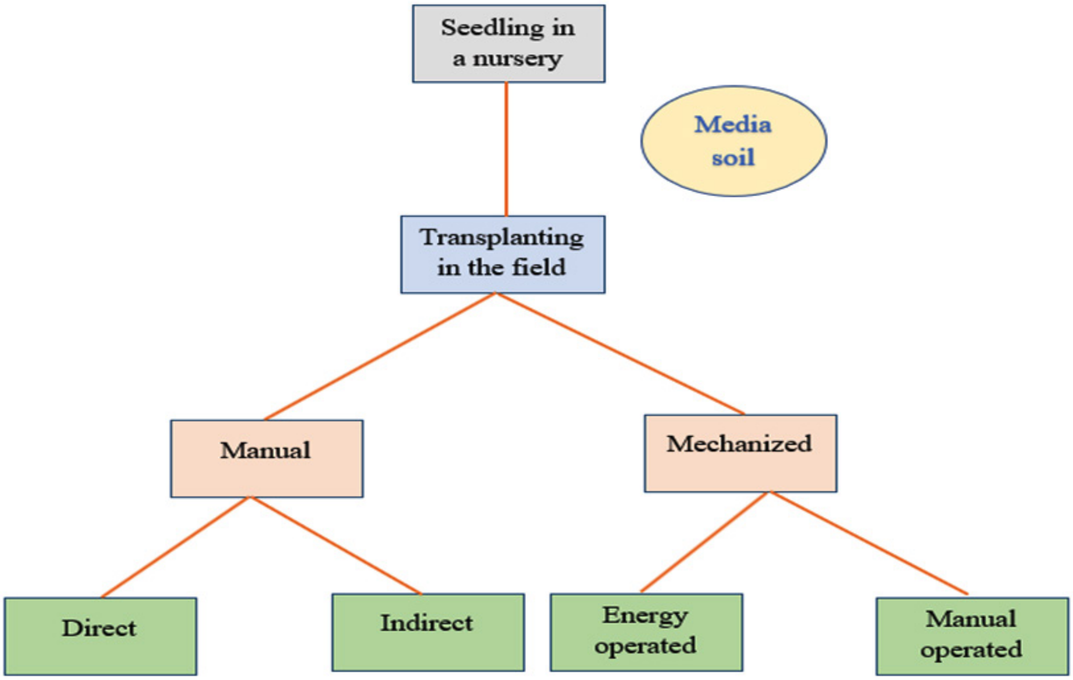

Fig. 3. Methods of rice cultivation by transplantation

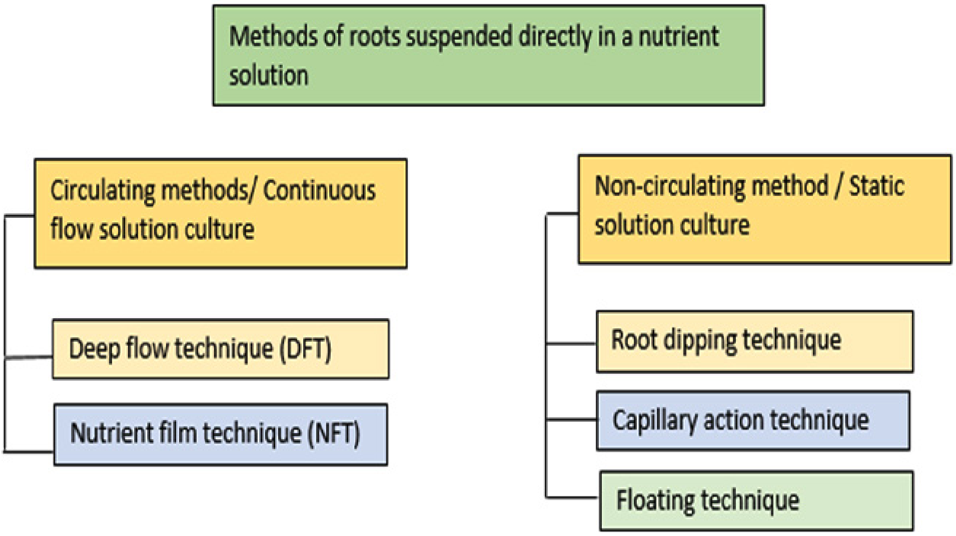

Fig. 4. Methods use in hydroponic technique

already been studies on it. Rice yield was boosted using brick planting media and nutrient solutions up to 13.6 t/ha. In hydroponic systems as opposed to non-hydroponic systems, the Sintanur variety of rice had a higher percentage of productive tillers. [50]. Additionally, the EC and pH of the nutrient solution were improved by the use of rice husk silicate extract as planting media in a hydroponic system [51].

Even in areas with poor soil fertility and scarce water resources, hydroponics has the ability to feed a sizable fraction of the world's population and enable third-world nations to feed their own populations. In areas with limited space,

Table 1. Different methods to grow rice and their advantages, disadvantages and limitations

Method	Advantages	Disadvantages	Factor affecting
Transplantation rice • Manual • Mechanical	Weed control Less seed required Manual or energy-operated	Labor dependent Large quantities of GHGs emissions Water scarcity Extensive energy Micro-nutrient deficiency	Transplanting time Type of soil Water availability Labor availability
Hydroponic rice • Circulating method	Appropriate for areas without enough fertile soil or arable	Demands technical expertise and a large initial investment.	Due to the system's limited ability to buffer nutrients
• Non-circulating method	land for agricultural culture. It is possible to achieve higher, reliable yields over time. Greater planting density and effective nutrient control.	Maintaining the medium's pH, electrical conductivity, and proper nutrient concentration is crucial.	and the danger of making quick alterations, regular monitoring of the system is necessary. pH, temperature, and the amount of nutrients
Direct seedling • Direct sowing in puddle of soil, prepared seed bed.	Saving energy, water use for irrigation, labor, time, better growth of succeeding crops, reduction in GHG emissions	Poor crop establishment, Increased soil-borne infections, the development of weedy rice, lodging, nutritional disorders, the occurrence of blast, and brown leaf spot.	Depth and spacing of the seeds, dryness and wetness of soil, nutrient dynamics.

Table 2. Rice cultivars for salt, drought and herbicides resistance

Rice Cultivars / Varieties	Region	Type	Reference
Pokkali, Kuliyadichan, Gurukot, IR12L-107, FL478, Genotypesviz	India	Salt tolerant	58
Chin.13, Kala Rata 1-24, Bhura Rata, SR 26B, Nona Bokra, 349 Jhona.	India and the Philippines	Salt tolerant	59
BR203-26-2, BRI, Sail	Bangladesh		
Lansheng, Mantaro rice, Hama, Minoru, Kanto 51, Chikushiqing	Japan		
Nonganbyeo , Dongjinbyeo, Ilpumbyeo, Seomjimbyeo, Ganchukbyeo, Gyehwabyeo,	Korea		
Kanchon ,Ghunsi, Nonabokra, Holdegotal, Hogla, Vusieri	Bangladesh	Salt tolerant	60
Sahbhagi Dhan (IR74371-70-1-1)	India	Drought resistant	61
Aigeng10, Yundao1, Wuyunjing7, Zaoxian14, Teqing, Xiushui04, Nantehao, Chazhan1, Dijiaowujian, Hongkenuo, Changlixian, Jiefangxian, Zhongnong4, Qing'er'ai	China	Drought resistant	62
IRGA 422CL	Brazil	Herbicide resistant	63
Ld365, Bg359, Bw364, At362, Bg369, Bg366, Bg403, Bg379-2, Bg454 Pachcha perumal, Kurulu thuda, Kalu heenati	Sri Lanka	Herbicide resistant	64

the technique can also be a valuable source of food production. Non-soil growing medium can be used in hydroponics to give roots mechanical support so they can sustain the plant's weight and stand upright. In hydroponics, media such as gravel, peat moss, river rock, sand, oasis cubes, rockwool, floral foam, perlite, vermiculite, coir, coco-peat, and sawdust are frequently used [52]. Sub-irrigation and top-irrigation are the two basic variations for each medium. It is nonetheless categorized as follows: 1. the hanging bag method 2. The grow bag method 3. Use of a trench or trough 4. The pot method [53].

Roots can thrive in a steady nutritional environment with the help of flowing solution culture systems. They are quite adaptable to automatic control, but if the flow of solution ceases for any reason, they are vulnerable to rapid plant desiccation. As a result, constant care is needed. Polythene beakers, pots, glass jars, and containers lined with black polythene film are all appropriate vessels for static systems.

Direct Seedling Rice (DSR)

The hunt for such alternative crop establishment techniques that can boost water productivity is prompted by growing water scarcity, a greater need for water for rice farming, and rising labor costs. The only practical solution to decrease the wasteful water flows is direct seeded rice. Instead of transplanting seedlings from a nursery, DSR refers to the process of starting a rice crop from seeds sowed in the field. Since the 1950s, it has been acknowledged as the primary way of growing rice in developing nations. Pre-germinated seed can be sown directly into a puddle of soil, a body of water, or a prepared seedbed. Farmers were urged to switch from the conventional system of transplanting to DSR culture by improved short duration and high producing varieties, nutrient management techniques, and weed management methods [54].

Germplasm/Cultivars of Rice crop

National research programmers and International Agricultural Research Centers of the Consultative Group on International Agricultural Research maintain rice germplasm collections, ranging in size from a few hundred to several thousand accessions, in a number of different nations. It has been economically valuable to take advantage of the genetic variety seen in rice [55]. The establishment of several functional genomics platforms, such as the gathering of germplasm resources and creation of mutant libraries, gene expression microarrays, RNA-sequencing (RNA-seq) and full-length cDNA libraries technologies for expression profiling, has occurred over the past ten years since the completion of whole-genome sequencing in rice [56]. Platforms for proteomics, phenomics, and metabolomics have all been gradually developed. The rice industry has also established corresponding platforms for bioinformatics analysis and databases [57].

Limitation of growing rice for research purposes

Limitation in Lab scale production

Without certain fundamental tools or circumstances, it is difficult to create any micropropagated materials in a Plant tissue

Table 3. Methods for the detection of rice diseases

Disease	Method	Reference
Rice Blast, Bacterial blight, Sheath blight	Collect disease-related images first, then use 2DFM-AMMF to denoise the image. Next, Faster 2D-Otsu is used to segment the noise-reduced image and extract the target leaf lesion from it. Last but not least, the FCM-KM and Faster R-CNN-based rapid rice disease detection approach was used to extract rice disease characteristics and categories pests.	83
Bacterial leaf blight, Leaf smut and Brown spot	Otsu's technique is used to segment diseased photos. Utilizing "Local Binary Patterns (LBP)" and "Histogram of Oriented Gradients (HOG)" to distinguish different features from the segmented area. Then, with the help of a Support Vector Machine (SVM), the features are categorized. Polynomial Kernel SVM and HOG were applied to achieve 94.6% classification accuracy.	84
Rice leaf blast	It includes pre-processing, image segmentation, and image analysis using the Hue Saturation Value (HSV) colour space. Image segmentation, the most important task in image processing, was used to isolate the illness region, and pattern recognition built on the Multi-Level Thresholding methodology was implemented. As a result, three categories—infection stage, worst stage, and spreading stage—were created to describe the severity of the RLB disease.	85

culture (PTC) laboratory. For proper controlled-environment conditions, these comprise complete infrastructure and qualified personnel [65].

• In vitro plant contamination is thought to be a major barrier to a successful micropropagation strategy. Numerous microorganisms, including bacteria, fungi, moulds, and yeasts, may be present in contaminated materials. The primary cause of PTC-related time and effort loss and consequent rise in production costs is contamination. Internal contamination is related to endophytic microorganisms in mother plants, whereas external contamination arises from laboratories and used objects (media; glassware; culture vessels, instruments, explants) [66].

• According to various studies, the in vitro propagation technique has five steps that must be followed: (1) pre-establishment; (2) establishment; (3) multiplication; (4) rooting; and (5) acclimation. A delay in culturing does, however, occur due to the PTC laboratories' tremendous workload, lack of equipment, and scarcity of technical specialists and experienced personnel. The creation of in vitro plantlets and even the upkeep of stock cultures will undoubtedly suffer greatly from this delay [67].

• The polyphenolic chemicals, which are well-known PTC inhibitors, are oxidised by enzymes, which causes the browning of explants or phenolic browning, a condition that occurs naturally. Polyphenol oxidases (PPOs) and peroxidase (POD) then convert the phenols generated from damaged or cut explants to quinones, browning the tissues and media as a result [68].

Limitation of rice production modelling in Field

An attempt to capture real-world occurrences in a research and computer simulation model is to grow rice for experimental purposes using models. Its goals are to describe real-world occurrences, forecast short- and long-term outcomes of a problem, provide potential policy remedies, and—most importantly—provide a more thorough understanding of a phenomenon or problem that exists. On this knowledge, it is hoped that the best course of action can be taken. Many experts contend that outcomes from such research-based studies on rice development are frequently regarded as being misdirected, or at the very least exceedingly fragile, because the quantification of qualitative factors employed in modelling dynamical systems frequently produces uncertainty As a result, field-based limitations must be created in research-based production in order to accurately depict phenomena and further understanding of such phenomena or challenges. Rice production is 1. 2. Consistency of the rice supply 3. Difference in rice and rice prices 4. Utilizing technology 5. Farmer well-being [69].

Exogenous variables are those that affect the state and dynamics of the model but are unaffected by it, whereas endogenous variables are those whose value is decided by the interaction of the model contained in the causal circle. The variables that cannot influence or have an impact on the model are those outside the border. As was already established, factors affecting rice output include the size of the paddy fields, the yield of the rice types planted, the fertility of the soil, pest disturbance, and the level of rice cultivation. Due to the rising population in Bandung Regency, land conversion from agricultural to non-agricultural uses has an impact on the area of paddy fields. According to statistics and field conditions, the effect of soil fertility and insect disturbance prevents some rice types from reaching their maximum value (or ideal). Despite the fact that it is impacted by water availability, planting intensity cannot be maximized [70].

Particularly in the real world, the outcomes of the model's simulation of the basic scenario are not what can be predicted for future rice output. It is necessary to interfere in the model's sensitive variables in order to enhance the behaviour model for this reason. It is intended that by altering the behaviour of the model, different policies to ameliorate the real-world phenomenon can be developed [71].

The field surrounding landscape elements, microrelief (differences in field level or slope), soil characteristics, area weed occurrence, water availability, animal attack and human disturbances, poor human disturbances, farmer capability, disaster (fire), agrochemical applications, etc. may all affect the accuracy of the data obtained from rice cultivation for research purposes [72].

Diseases in rice Crop

Rice Blast

Rice blast caused by *Magnaporthe grisea* is the major damaging disease in nearly all rice growing nations. Economically relevance with 60 percent of total population of world depending on rice as the main source of calories, may have destructive effects of the disease, however, this pathogen has developed into a pioneering model system for researching host-pathogen interactions. The disease outbreak depends on the weather and climatic conditions of the various regions. The disease's occurrence and symptoms vary from country to country. Susceptible cultivars cause huge rice production loss in yield. The principal cause of resistance breakdown in rice against rice blast disease is pathogenic variability [73].

The causal agent is the fungus *Pyricularia oryzae* Sacc. with the perfect stage being called *Magnaporthe grisea* Sacc. The blast fungus is capable of infecting rice at any stage of the host life cycle. The disease appears early as white to gray (or brown) leaf spots or lesions on the leaf, followed by nodal rot and as neck blast. Changing climatic conditions can alter the degree of infestation of the rice crop by the pathogen. Moderate field infections can cause approximately 50% grain yield reductions. It has been estimated that *P.oryzae* destroys enough rice grain each year that could feed 60 million people. The effect of the actual climate changes should be taken into account. The disease can be severe during periods of cool temperatures and high moisture, while the inactive conidia (seeds or spores) do not germinate under direct sunlight [74].

Bacterial Leaf Blight (BLB)

The most severe bacterial disease affecting rice in the globe is called bacterial leaf blight (BLB), and it is brought on by Xanthomonas oryzae pv. Oryzae (Xoo). Massive crop losses are caused by the prevalence of BLB, even up to 50% of rice productivity being affected [75].

By employing 24-hour-old, fresh wounds, the pathogenic bacteria infect the rice crop plants through the water pores. Lesions typically begin at the leaf margins on the upper section of the leaf, close to the top area, since the higher area of the leaf has pores for water percolation. Small water-soaked lesions at first, which eventually turned yellowish white in hue, then grew outward from the square's equal sides to generate elongated circular to noticeably uneven lesions. The edges of the lesions were close to the healthy leaf tissue and had the disease's most recognizable symptom, wavy margins, which are quite visible on the leaf blade. Under humid conditions, the lesions might be seen on newly infected leaf veins or typically begin on one or both leaf margins. The environment was a major factor in the disease's emergence and the emergence of its symptoms in the field. The disease can be divided into two primary phases: the leaf blight phase and the "Kresek phase," which is the one that causes the epidemic of the disease to spread destructively [76]. In the case of BLB resistance in variant lines, molecular methods such as Western Blotting, Polymerase Chain Reaction, and morpho-molecular screening can be used to identify Xoo. Additionally, it is possible to detect Xoo occurrence using biochemical methods [77].

The most crucial tactic for controlling BLB in the past was thought to be resistant variation. Unfortunately, Xoo patho-types were a problem for technology. The remarkable Xoo mutability makes controlling the BLB very challenging. After three to four years, newly created resistant types were easily broken down. Due to the establishment of resistance to the Xoo pathogen in rice and the fact that this technology was only used during the vegetative phase, its limitations grew with time and geographically [78].

Brown Spot

Brown spot of rice, which is carried on by Shoemaker (Telemorph - Cochliobolus miyabeanus) Bipolaris oryzae (Breda de Haan), was one of many diseases that eventually led to sustained losses in both quality and quantity. Up to 90% of the crop could be affected by the disease, which also affects grain growth, discoloration, and marketability of the rice grain [79]. Since the Bengal famine of 1943, when nearly 2-3 million people perished from malnutrition as a result of low agricultural production, the infamous rice pathogen has had an effect on the rice business. Numerous fungi have been identified as the root causes of BS, each of which manifests its own unique set of symptoms in the host. For instance, B. oryzae, Cercospora oryzae, and Pyricularia oryzae are the culprits behind brown leaf spot, narrow brown leaf spot, and leaf blast, respectively [80].

From seedling through milky stage, the crop is under attack by the pathogen. The symptoms manifest as tiny spots on the coleoptile, leaf blade, leaf sheath, and glume, with the leaf blades and glumes showing the symptoms the most prominently. On leaves, typical spots have a golden halo around them and a brown color with a grey or whitish center that resembles a sesame seed [81].

Strategies for managing brown spot in rice were only sporadically investigated in areas where resistant cultivars were underdeveloped. But the chemical control of B. oryzae was a very quick, efficient, and affordable measure [82].

Zineb, one of the earlier advised drugs, proved ineffective when the inoculum pressure was high. To lessen the severity of the disease and for efficient management of the brown spot disease, numerous chemicals with various modes of action and targets were combined in recent decades.

CONCLUSION

Majority of Asians, rice is an essential crop that is require for life. Rice is life for more than half of humanity. Rice production systems are divided into two groups based on the two main techniques used to plant rice around the world: transplanted rice (TPR) production systems, and direct-seeded rice (DSR) production systems. DSR production systems can also be divided into three subcategories: dry-DSR production systems; wet-DSR production systems; water-DSR production systems. When best management methods are used, it has been reported that TPR and DSR productivity are comparable. Due to benefits of DSR production systems, including lower cost of production, increased resource (water, labor, and energy) use efficiency, and income compared to TPR, a shift in adoption toward DSR production systems is taking place in the developing world, as it has already done in the developed world. Another method is Hydroponic system. There are different cultivars and germplasm used to cope with the issues of drought, excess amount of salts and diseases. Application in breeding is the ultimate goal of rice functional genomic research. Rice breeding tactics and technologies could undergo a radical transformation due to the knowledge, germplasms, genes, and genomic data currently available. There are also some limitations while conduction laboratory experiments and modelling of rice production for research purposes. Due to change in climatic conditions, rice crops undergo different diseases. There is need to establish new methods for the detection and identification of diseases at early stage of crop growth to minimize the effect.

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Conflict of Interest

Authors declare o conflict of interest.

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